PCB CONTAMINATION OF THE AQUATIC ENVIRONMENT

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The Honourable
William G. Newman,
Minister

Everett Biggs,
Deputy Minister

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PCB CONTAMINATION OF
THE AQUATIC ENVIRONMENT
IN ONTARIO.

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ABSTRACT

Sporadic analyses of sampling from the aquatic environment have shown that PCB's are universal pollutants. Almost without exception the contaminant was of the Aroclor 1254 type. The approximate levels were as follows: effluents from sewage treatment plants up to 0.1 ppm, river sediments up to 0.6 ppm, fish up to 20 ppm and seagulls up to 1500 ppm in fatty tissues.

In order to gain more detailed information, a systematic large scale survey was undertaken. Four different types of aqueous systems were studied: an industrialized "impound system", an industrialized "dynamic system", a natural "impounded system", a natural "static" system and a natural "dynamic" system. Water, bottom sediments and fish were analyzed, and the data obtained is presented and discussed. The analytical techniques - separation of PCB's from other chlorinated materials and the determination of PCB's in terms of the fully chlorinated derivative-decachloro biphenyl are discussed as well.

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FIG.1. General Map of Southern Ontario, Showing Sampling Areas.

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Thanks should also go to Mr. J. Osborne of our laboratory staff for his skillful technical assistance in carrying out the analysis for this program.

POLYCHLORINATED BIPHENYLS IN THE AQUATIC ENVIRONMENT IN ONTARIO.

The polychlorinated biphenyls, PCB's, are now recognized as the most widespread synthetic materials in the environment (1). The residues of these compounds have been identified in all areas of the biosphere (2). The general biochemical properties of the PCB's are poorly understood. However, at present there is enough experimental evidence to indicate that the toxicological properties of the PCB's are very close to those of chlorinated pesticides. Other studies have indicated that they are also extremely persistent in the environment; some of the materials are even more persistent than the chlorinated pesticides. There is no clear experimental evidence about the transport mechanisms for these materials. It appears however that aqueous systems play a major role in this respect. At the same time, since PCB's have been found in remote locations, air transport as one of the probable mechanisms cannot be ruled out.

Over the years, sporadic sampling of the aquatic environment in Ontario indicated that the PCB's are quite widespread. Practically all samples containing PCB residues, produced gas chromatographic traces similar to Aroclor 1254. The following concentration ranges were found: effluents from sewage treatment plants 0.01-0.1 ppm, river sediments, up to 0.6 ppm, fish up to 20 ppm and gulls up to 1500 ppm (based on oil).

In order to obtain a more detailed and representative picture of the PCB contamination in Ontario, a systematic survey was undertaken. Since Ontario covers about 400,000 square miles, one sixth of which is water, for practical purposes the survey had to be limited to certain representative areas (Fig. 1).

Four distinct types of aquatic systems were studied:

1. A heavily industrialized confined bay area - Hamilton Harbour (Fig.2).
2. An intensely industrialized, dynamic water body - St. Clair River (Fig.3).
3. A natural and mixed industrialized dynamic system - Ottawa River (Figs. 4).
4. A natural confined water body: - Twist Lake - a small northern lake receiving no industrial, municipal or recreational inputs. It was intended to provide a base line for the studies of the other areas (Fig.5).

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EXPERIMENTAL

1. Sampling

a. Waters

All water samples were taken in 40 oz. glass bottles previously solvent rinsed, and fitted with Teflon cap liners. All mechanical sampling devices were solvent rinsed to remove lubricants which might contain PCB's. No plastic liners or other plastic parts were used in these devices.

b. Sediments

All sediments were taken in wide necked sample jars (20 oz.) which were previously solvent rinsed and fitted with aluminium foil lined caps. Similar precautions were taken to avoid lubricant or plastic contamination from dredges.

c. Fish

All fish samples were frozen and stored at -10°C until dissected. Samples of muscle tissue were taken below the dorsal fin where possible, and stored frozen in aluminium foil cups, after homogenization. In the case of small fish, the whole fillet was sometimes required.

2. Analysis

a. Extraction

i. Water

Water samples were transferred to a 2 litre separatory funnel, with Teflon stopcock. The sample bottle was rinsed with 100 mls of methylene chloride, which was then transferred to the separatory funnel and used to extract the sample. This process was repeated with 3x50 ml solvent aliquots. The combined aliquots were dried over anhydrous sodium sulphate, filtered through a glass wool plug, and evaporated to -2-3 mls on a rotary evaporator. This concentrate was then subjected to hydrolysis and acid treatment as described in 2b.

ii. Sediments

100 gm aliquots were air dried at 40°C to constant weight 50 gms were then weighed into a 500 ml erlenmeyer flask, 5 mls of distilled water added, and then 100 mls of

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acetonitrile. The samples were stoppered and shaken on a wrist action shaker in a fume hood for 8 hours. After settling, the acetonitrile extract was filtered through a glass wool plug, and collected. The extraction was repeated with a further 100 ml solvent-aliquot. The combined extracts were dried over anhydrous sodium sulphate and concentrated on a rotary evaporator to 2-3 mls, then submitted to treatment as in 2b.

iii. Fish

10 gm aliquots of fish homogenate were weighed out into 125 ml erlenmeyers, then submitted for treatment as in 2b.

b. Clean up

The extracts from step 2a, and fish aliquots were saponified for 1 hour on a steam bath with 20 ml 40% potassium hydroxide in ethanol. After cooling, the samples were transferred to 125 ml separatory funnels, and extracted with 2x25 ml of hexane. The hexane extract was evaporated gently to dryness under a nitrogen stream and 10 ml of a 12% solution of chromium trioxide in glacial acetic acid was added. The sample was boiled for 30 minutes on a steam bath, then cooled and extracted with 2x20 ml of hexane. The combined extracts were back-washed with 15 ml of a saturated sodium bicarbonate solution, then 2x20 mls of water, dried over anhydrous sodium sulphate, and concentrated under a nitrogen stream to 1 ml. The concentrate was then cleaned up on a Florisil column (16 cm x 0.6 cm), eluting the PCB's with 16 mls of hexane. After concentration the eluate was subjected to gas chromatography for PCB determination.

c. Quantitation

Gas chromatographic measurements were done on a Varian 1400 gas chromatograph equipped with a Ni_{63} detector and a 6'x1/8" glass column containing 11% OV17/QF1 on Gas Chrom. Q. Column temperature was 205°C, N_2 flow at 40 ml/min. Quantitation was carried out in two steps:

1. Matching up the fingerprint as closely as possible with one of a series of known PCB standard.

2. Quantitation by comparison of a sum of peak heights for these peaks which could be matched up with the standard, usually 9-10 peaks.

3. Quantitation was checked by perchlorination of every 6th sample (3). Results using these techniques usually checked

to ± 15% of those by the peak-height-sum method.

Recoveries for the Peak Height-Sum Method, Based on Spiked Samples, were as follows:

Fish, 95% - 100% recovery. Detection limit - 5 ppb.
Water, 95% - 103% recovery. Detection limit - 0.01 ppb.
Sediment, 70% - 80% recovery. Detection limit - 1 ppb.

AREAS UNDER INVESTIGATION

Hamilton Harbour

Fig. 1 shows the location of Hamilton Harbour at the far western end of Lake Ontario. Fig. 2 gives a detailed outline of the harbour. It is roughly triangular, 6 miles long, and 2.5 miles wide. Surveys carried out by various agencies from 1950 onwards have indicated quite clearly that Hamilton Harbour is a heavily polluted water body. This condition may be attributed to several interacting factors. Firstly, the harbour is almost completely impounded, the only outlet being the shipping channel. This, combined with a total yearly input of only 35% of the total volume (60% municipal/ industrial, 40% surface drainage), produces a relatively static situation. Considering also the high level of recirculating industrial discharge (240% of total Harbour volume) the lack of full treatment of much of this industrial effluent, and the discharge of untreated sewage at times of high flow, it is fairly obvious why Hamilton Harbour is heavily polluted. The south shore of Hamilton Harbour houses the major industrial source of pollution - a giant industrial complex concerned with manufacture and fabrication of steel. As well as the phenolics and ammonia discharges by such operations as coking ovens, PCB's can be considered as one of the more significant pollutants from the steel making process. The south end corner of the Harbour is also the site of Hamilton sewage treatment plant; such plants have long been implicated as major sources of PCB discharge.

Sampling points are shown in Fig. 2.

Six sediment samples were taken in 1971 (Table 1). The initial indications of PCB residues prompted the further more detailed sampling in 1972, when fish, sediments and waters were taken (Tables 1 & 2). The presence of fish in certain areas of the harbour is possibly significant. These fish appeared to be only 1-2 years old, indicating that recent cleanup efforts may be bearing fruit.

Results documented in Table 1 indicate that Hamilton Harbour is the most contaminated area of the four studied for PCB residues. Results indicate that, as expected, one major

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source is the Hamilton sewage treatment plant. Both water and sediment samples in the area of the plant outfall show high PCB values (Station 10 - water 0.45 ppb, sediment 10,000 ppb). These values gradually fall off as sampling points move away from the plant, until the "clean" side of Hamilton Harbour (North side) is reached (Station 3 - water 0.095 ppb, sediment 600 ppb). In comparison with 1971 figures, sediment levels near the STP are lower by a factor of 5 this year.

The possible explanations for this discrepancy are:

(a) Increased sediment deposition from new land fill areas,

(b) non homogeneity in sampling,

(c) decrease in PCB's in waste treatment plant effluent, or a combination of these factors.

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TABLE 1.

PCB SAMPLING PROGRAM - HAMILTON HARBOUR
PCB LEVELS IN WATER AND SEDIMENT

Station	Water, 1972 in ppt.	Sediment, 1971 in ppm.	Sediment, 1972 in ppm.	Sediment Type	Type of PCB.
1			0.8	Brown Clay	
2			2.0	Silt and clay	
3	95		0.6	Silt	
4	35		3.0	Silt	
5			1.05	Sand	Aroclor 1260 (close fit)
6	Trace		1.3	Fine clay	
7	57	20	0.17	Silt	
8			0.23	Sand	
9	38		0.66	Silt	
10		46	10.1	Silt	
11			0.22	Sand and Organic matter	
12		2.5		Black Muck	
13		0.4		Sand and Clay, Oily	
14		0.7		Black muck, oily	
15		23.0		Black muck, oily	

TABLE 2.

PCB SAMPLING PROGRAM - HAMILTON HARBOUR
PCB LEVELS IN FISH

Species	Number of Samples	PCB Range in ppm	Average	PCB Type Aroclor	Weight Distribution in Grams
Carp	9	0.24-11.6	3.6	1260	150-1350
Shad	8	0.92-3.1	2	1260	450-600
White Bass	10	1.0-5.6	2.3	1260	250-500

St. Clair River System - Figures (1 & 3).

The river, the connecting waterway between Lake Huron and Lake St. Clair, flows in a southerly direction for about 40 miles. The upper channel, about 28 miles long, has an average width of about half a mile. The depth runs between 25-27 feet. The St. Clair River is actually a very large, and in places a very fast running river. The average flow is at least 177,000 cfs. The water uses in the river include public water supplies, industrial water supplies, waste assimilation, cooling water for steam electric power generation, recreation, boating, fishing and commercial navigation. The water quality management of the river is rather difficult. At present, there are more than ten major chemical plants located along the upper channel, on the Canadian side, the so-called Chemical Valley. These include a number of petroleum refineries, petro-chemical plants and other synthetic chemical plants. Although considerable progress has been made in improving the quality of water in recent years, the situation is not yet entirely under control. Part of the problem may be attributed to the quality control methods used before by which the water quality has been monitored in terms of gross pollution parameters, such BOD, as COD, dissolved and suspended solids. The more subtle pollutants, in terms of their physiological actions, e.g. pesticides and PCB's and for that matter mercury, have, up until recently, not been considered critical as far as monitoring and control measures are concerned.

St. Clair River/Lake St. Clair

Due to the high flow, PCB results from this river must be interpreted in fairly general terms. Even so, they yield quite an interesting picture. Results are summarized in tables 3 & 4.

Levels at station 1, in Lake Huron are relatively low (water 0.02 ppb, sediment 0.1 ppb) as might be expected. At consecutive and more southerly sampling points, water concentrations rise rapidly to a maximum of 0.9 ppb at station 3, located at the centre of the main industrialized section, in the northern parts of the river. Sampling points downstream of this show a rapid drop, to a relatively consistent 0.03-0.07 ppb range. Sediment concentrations also rise to a maximum (600 ppb), but at sampling point 5, some 2-3 miles downstream of the point of water maximum, again pointing to possible PCB/sediment inter-actions. Downstream levels again fall off rapidly. Note should also be made of the significant increase in sediment PCB values at point 8. This is at the beginning of the delta on Lake St. Clair. At this point the water velocity drops drastically, and one would expect considerable sedimentation to occur, producing a possible build up of PCB's due to

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the adsorption of these compounds to the deposited sediment.

Fish data shows some interesting features. Although the highest concentrations in fish, were noted in white bass taken at station 7, halfway down the river at Clay Creek (12 ppm), levels were still high in fish from the Delta area around Channel Ecarte. As noted earlier, this area also shows elevated levels when compared with sampling points immediately north of it in the river.

Samples of perch and pickerel from Lake St. Clair showed low levels (perch 0.15 ppm, pickerel 0.9 ppm) in comparison with those taken in the river itself.

TABLE 3

PCB SAMPLING PROGRAM - ST. CLAIR RIVER
PCB LEVELS IN WATER AND SEDIMENT

Station	Water in ppt	Sediment in ppb	Sediment Type
1	23	<0.1	Heavy gravel
2	230	2	Clay
3	900	125	Coarse Sand
4	45	190	Clay
5	75	600	Sand and Silt
6	38	33	Sand
7	50	43	Sand and Silt
8	32	120	Sand and Silt

TABLE 4

PCB SAMPLING PROGRAM - ST. CLAIR RIVER
PCB LEVELS IN FISH

MINISTRY OF THE ENVIRONMENT, LABORATORY BRANCH

Species	Number of Samples	PCB Range in PPM	Average	PCB Type Aroclor	Weight Distribution in Grams
		ST.CLAIR RIVER			
White Bass	5	4.3-12.3	7	1254	330-670
Pike	11	0.1-6.8	2	1254	960-3000
Common White Sucker	22	0.1-2.8	1.4	1254	400-1100
Cohoe Salmon	4	1.5-4.7	3.10	1254	900-1400
		LAKE ST. CLAIR			
Perch	12	0.1-0.25	0.16	1254	
Pickerel	38	0.2-3.0	0.7	1254	200-2000
Pickerel	8	0.7-1.1	0.9	1254	160-210

Ottawa River Area (Figs. 1 & 4).

The Ottawa River Basin drains an area of approximately 56,000 sq.miles. The River itself is about 380 miles long and is the largest tributary to the St. Lawrence River. Like many other rivers in glaciated regions, the Ottawa River consists of a chain of lakes connected by sections of rapids and waterfalls. The main annual flow varies with the location, from 16,000 to 73,000 cfs. Economically it is a rather important river. This importance is among others reflected in the amounts of wastes the river receives. Approximately 380,000 lbs. of suspended solids are discharged daily from which the contribution of the paper and pulp mills is about 376,000 lbs. or 99%. The oxygen consuming wastes, exposed as BOD, amount to approximately 1,200,000 lbs. a day from eight paper mills, which is about 90% of the total industrial waste load. In addition to the industrial wastes there are contributions from the 38 municipalities in terms of treatment plant effluents. The total daily load from them is about 70,000 lbs of BOD, about 6% of the total BOD load. These figures are appalling, but they certainly do not mean that the river is an open sewer. On the contrary, they reflect the remarkable recuperative powers of large bodies of water. Admittedly there are a number of polluted areas, particularly immediately below the pulp and paper mills. The previous use of phenylmercuric acetate as a slimicide has closed certain areas for fishing. In addition, certain areas near the paper mills have no fish because of oxygen depletion. Nevertheless there is a viable tourist and commercial fishing industry. Perhaps the following pieces of information, from an official survey, shows it more clearly. At a certain part of the river it was found "that during a period of 42 days from June 26th to September 25th, 1969, 386 anglers fished for a total of 584 hours and caught 1040 fish for an average of 1.78 fish per angler hour, an excellent rate of return.

Sampling was carried out for fish, water and sediment along the major portion of the Ottawa River to give some indication of the effect of both individual industrial inputs and heavier concentration of industrial and municipal inputs, such as exist around Ottawa. Previous sampling of fish and sediments near Ottawa had indicated quite high PCB levels (fish 0.7 ppm, sediment 40 ppb). Fig. 4 is a map showing the section of the river studied, with the major industries and towns and the sampling points. Fish samples were taken over sections of the river as indicated in table 6. Table 5 gives water and sediment results.

As might be expected, the lowest PCB level in water is at the control station above Temiskaming (0.01 ppb). Concentrations then show a gradual increase at downstream sampling points,

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until a maximum of 1.6 is reached at the Chenaux Dam, below the Consolidated Bathurst Pulp Mill. Levels then decline somewhat, but remain as high as 0.4-0.7 ppb, until stations below Ottawa are reached.

Values then fall off considerably, to as low as 0.01 ppb near Thurso. However, maxima can still be observed near large municipal or indistrial areas such as Hawkesbury STP (0.5 ppm) and Oka Ferry near Montreal (0.7 ppb). Sediment concentrations also show a similar pattern of variation. However, maxima in this case usually show up at stations somewhat downstream of those that gave water maxima. Such a variation could be explained by the normal downstream sediment deposition and movement carrying the PCB's along. Data on sediments is sparse, and it is hoped that further sampling will establish the concentration trend more distinctly.

Concentration distributions in fish taken from the Ottawa River show the usual geographic smoothing tendencies of mobile fish populations. Results are shown in Table 6.

A distinct increase in PCB concentration is noted in fish taken in and around Ottawa. Pickerel from upstream of Ottawa (Pembroke area) show an average of 0.04 ppm, at Ottawa approximately 0.25 ppm and below Ottawa 0.08 ppm. Carp and Sturgeon taken in the Ottawa area are also high (carp 1.0 ppm, sturgeon 1.1 ppm on average).

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TABLE 5.

PCB SAMPLING PROGRAM - OTTAWA RIVER

PCB LEVELS IN WATER AND SEDIMENT

	Water		Sediment		
Station	in ppt	Type PCB Aroclor	in ppb	Type PCB Aroclor	Sediment Type
1	10	1254	2	1260	Sand and Gravel
2	25	1254			
3	76	1254	60	1260	Sand and Gravel
4	140	1254			
5	510	1254	3	1254	Sand and Gravel
6	1580	1254	50	1254	Silt, Decaying Organic Matter
7	420	1254			
8	22	1254	130	1254	Gravel, decaying organic matter
9	460	1254	60	1254	Gravel
10	680	1254			
11	90	1254			
12	230	1254	3	1254	Gray clay
13	11	1254	2	1254	Sand
14	22	1254	47	1260	Silt
15	520	1254			
16	12	1254	130	1260	Mud
17	122	1254			
18	670	1254	50	1254	Clay, muck.

TABLE 6

PCB SAMPLING PROGRAM - OTTAWA RIVER
PCB LEVELS IN FISH UPSTREAM FROM OTTAWA.

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LABORATORY BRANCH

Species	Number of Samples	PCB Range in ppm	Average	PCB Type Aroclor	Wt.Distribution in grams
Pickerel	7	0.03-0.09	0.04	1254	200-400
White Sucker	5	0.03-0.05	0.04	1254	300-700
Perch	3	0.01-0.13		1254	150-200
Pickerel	7	0.02-0.05	0.04	1254	300-600
Silver Red-Horse Sucker	3	0.03-0.9		1254	
		OTTAWA REGION			
Pickerel	6	0.16-0.30	0.23	1254	200-500
Pike	12	0.05-0.15	0.10	1254	300-1200
Brown Bullhead	6	0.13-0.42	0.28	1254	280-400
Channel Catfish	7	0.11-0.24	0.18	1254	400-1700
		DOWNSTREAM FROM OTTAWA			
Pickerel	12	0.04-0.27	0.08	1254	1200-3600

Twist Lake

This is a small lake 20 miles north east of Mattawa (see Figs. 1 & 5). As a reference point or baseline for this study, an attempt was made to select an isolated water body, whilst still under similar natural environmental influences to those encountered by the other areas sampled, would be free from any industrial, municipal, recreational, or other artificial inputs. As the results in Table 7 show, finding such an area is not as simple, these days, as it might seem.

Twist Lake is typical of the many land locked lakes of Northern Ontario. It has no tributaries. Human activity is virtually absent, the only exception being a disused cottage shown on the map (Fig. 5). Highway 533, running to the west of the lake is a small gravelled road. The lake is quite typical, having a rather rocky shore, with a sand, silt and mud bottom. A small stream leaves the east side of the lake, and drains into the nearby Ottowa River.

PCB results on samples from Twist Lake are somewhat unusual. It was anticipated that the lake would contain fairly low background levels with little fluctuation attributable to general atmospheric transport and fallout.

Table 7 shows results for water and sediments from the lake. No fish were taken. Water and sediment results in the eastern and western arms of the H-shaped lake are unexceptional, (water average 0.014 ppb, sediment 25 ppm). However, results for stations 2 and 6 are markedly different from the others. Station 3 has a sediment PCB level of 270 ppb, water 0.6 ppb and station 6, the sediment has a PCB level of 16 ppb, water 0.55 ppb! Station 9 also has a somewhat elevated, 70 ppb sediment, PCB level.

Speculation as to the causes of this localized pollution is difficult, The nearby gravel road is oiled for dust control, but the nearest contact point to the lake shows no PCB concentration increase in the lake.

It has also been pointed out that a major jet airliner route passes directly over the lake. Although PCB's have been used as an engine lubricant in such planes, it is unlikely that so localized a case of contamination could originate from jets flying at fairly high altitudes. Further studies of this lake are contemplated, with a view to checking contamination from the road oiling, airborne PCB's or other causes.

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TABLE 7.

PCB SAMPLING PROGRAM - TWIST LAKE
PCB LEVELS IN WATER AND SEDIMENT

Station	Water in ppt	Water Type PCB Aroclor	Sediment in ppb	Sediment Type PCB Aroclor	Sediment Type
1	13	1254	14	1254	Mud
2	6	1254	14	1254	Silt
3	610	1254	270	1242-1254	Mud and Sand
4	22	1254	14	1254	Silt
5	17	1254			
6	550	1254	16	1254	Silt and Mud
7			23	1254	
8			9	1254	Silt and Mud
9			70	1248-1254	Silt (in terms of Aroclor 1254)
10			40	1248	Mud
11			20	1254	Mud
12			23	1254	Silt

Discussion and Conclusions

Due to the relatively small number of areas sampled, few conclusions of general application to the aquatic environment in Ontario can be drawn from these results. We can, however, make the following observations.

(1) PCB concentrations in the areas sampled are on the whole, closely related to the degree of local urbanization or industrialization. Areas such as Hamilton Harbour, with restricted water movement tend to build up higher concentrations in all phases of the aqueous system than those in relatively well flushed areas.

(2) PCB's in water appear to be bound to particulate matter, as might be predicted by their practical insolubility in water. This is indicated by the rapid rate of decrease of PCB concentration in water below discharge points of high PCB output. Slow moving, semi-impounded systems such as Ottowa River, have a rapid drop-off of PCB levels in water, corresponding to their fairly high sedimentation rates. Areas of high flow such as St.Clair River with corresponding lower sedimentation rates, maintain their high PCB concentrations in water for a considerably longer downstream distance. Areas of little or no flow (Hamilton Harbour) tend to build up extremely high PCB levels in sediment close to discharge points such as sewage treatment plants, these lvels dropping off rapidly further away from the outflows.

(3) Although it is relatively easy to locate (on theoretical grounds only) areas of high PCB contamination, it is not nearly so simple to predict areas of low PCB contamination, if in fact such do exist today. It is possibly this contamination of remote areas by unknown sources and mechanisms which may present one of the more important problems in the study of PCB transport and build up.

With the anticipated restrictions of PCB uses in Ontario, it would be of considerable benefit to identify and study present day "hot spots" of PCB build up, and to follow, by monitoring the effect of reduced usage on environmental levels.

It has been postulated that even a total half of PCB introduction to the environment will not cause an immediate decrease in PCB residues.

It might be expected that the existing environmental "pool" of PCB's could cause continuing increase in levels in wild life and other organisms high in the food chain such as man,

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for some time before any decrease is apparent. At present, understanding of the effects of this type of pollutant on mammalion organisms is not complete enough to predict the future results of such continued accumulations.

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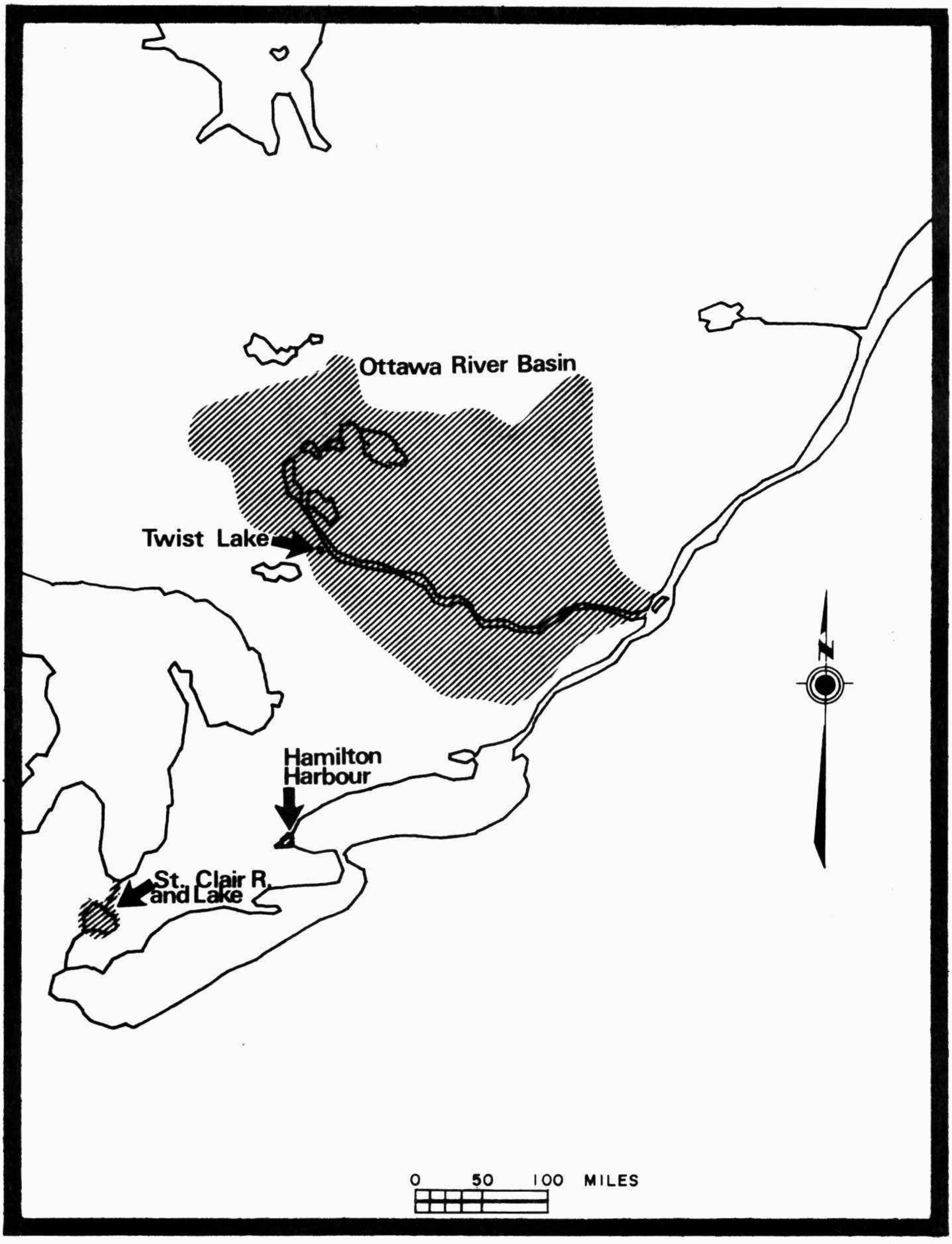
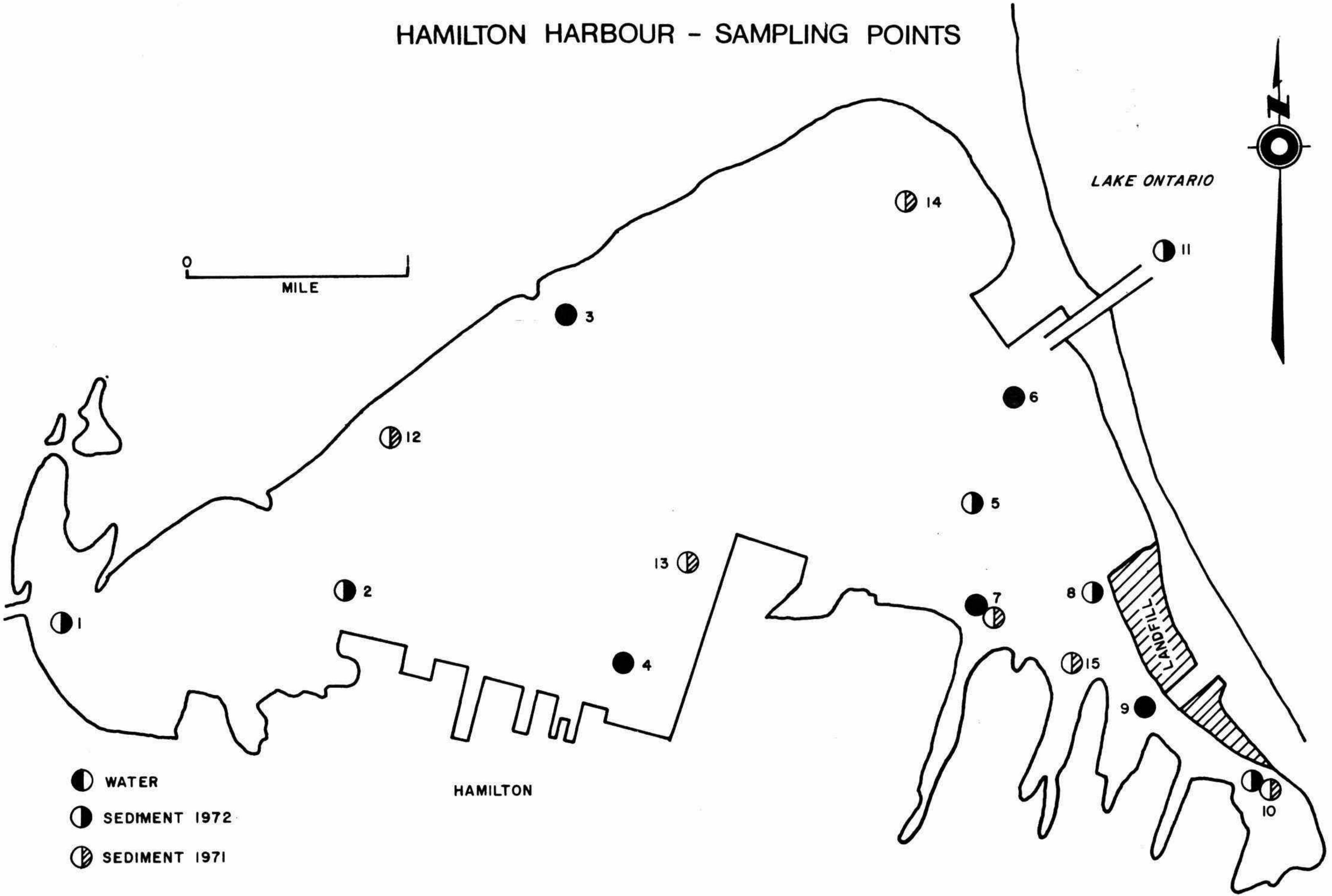
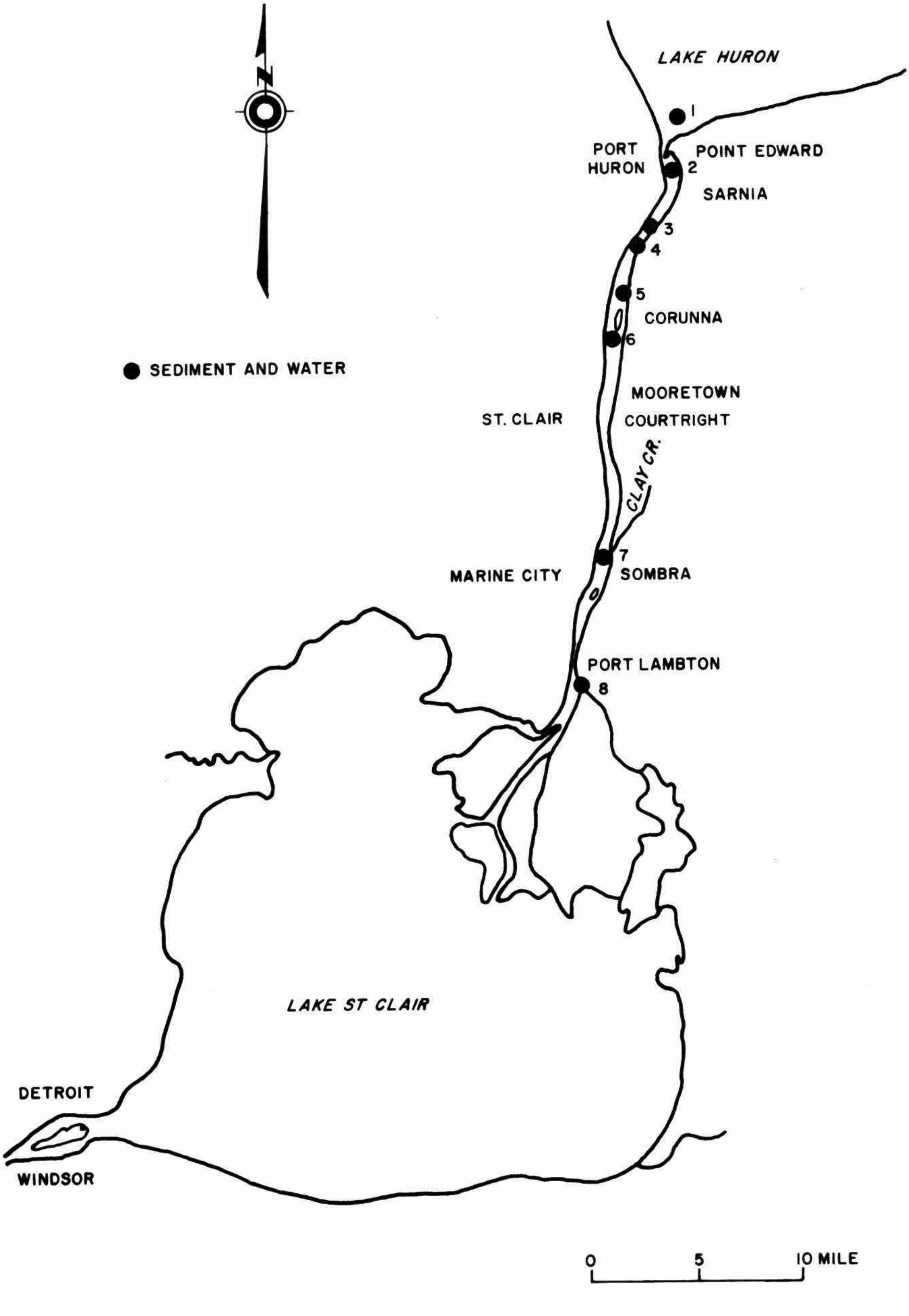
GENERAL MAP OF SOUTHERN ONTARIO SHOWING SAMPLING AREAS



HAMILTON HARBOUR - SAMPLING POINTS



ST. CLAIR RIVER / LAKE ST. CLAIR - SAMPLING POINTS



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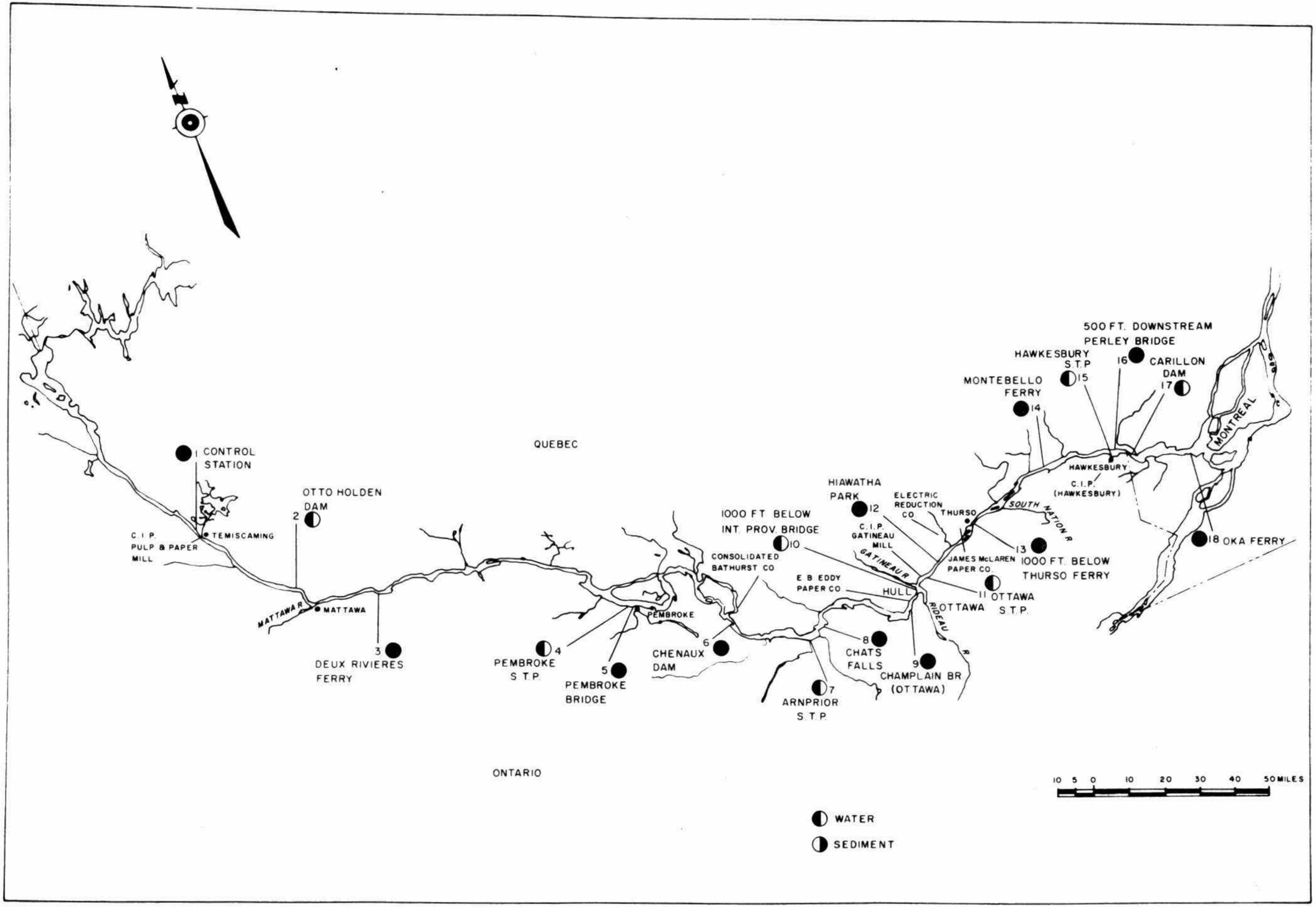

TWIST LAKE - SAMPLING POINTS